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Effects of Soil Type and Watering on Germination, Survival, and Growth of Engelmann Spruce: *A Greenhouse Study*

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Watering treatments affected both germination and survival; soil type affected survival only. Root elongation was significantly different between soils with adequate water, but top height and total plant dry weight were not significantly related to either soils or watering treatments.

Keywords: *Picea engelmannii*, plant soil-water relations, plant physiology, seed germination.

The amount and distribution of precipitation during the growing season are important factors affecting the germination and early survival of Engelmann spruce (Picea engelmannii Parry) (Alexander and Noble 1971). Regeneration success on the Fraser Experimental Forest in central Colorado has been better on one soil than another, however, even under similar precipitation patterns.

The study reported here was made under controlled greenhouse conditions in 1970 to supplement field observations. Germination, initial survival, and growth were compared on two soils under watering treatments selected to represent a common precipitation pattern on the Fraser Experimental Forest (Alexander and Noble 1971, U.S. Weather Bureau 1931-70).

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Methods and Materials

Seed source.—Engelmann spruce seeds collected at 9,500 feet elevation in 1967 on the Routt National Forest in Colorado were used. Average laboratory germination was about 75 percent.

Soil and seeding.—Two forest soils from 10,500 feet elevation on the Fraser Experimental Forest were used. Bobtail soil, a gravelly, sandy loam, is a Sols Bruns Acides which developed in place under a mixed spruce-subalpine fir (Abies lasiocarpa (Hook.) Nutt.) lodgepole pine (Pinus contorta Dougl.) stand from gneisses and schists that were metamorphosed from granitic rock. Weathering has been slow, and as a result the soil contains a large amount of sand and gravel (Retzer 1962). Darling soil, a gravelly, sandy loam, is a Podzol developed in place under a spruce-fir stand from coarse-textured material weathered from mixed gneisses and schists.

Each soil was screened through 4-mesh hardware cloth and thoroughly mixed. Moisture content at tensions of 1/3 and 15 bars, determined in the laboratory, were approximately 18 and 9 for the Darling soil, and 15 and 8 percent for the Bobtail soil, respectively. Mechanical analyses showed approximately 56, 34, and 10 percent sand, silt, and clay, respectively, for the Darling soil, and 54, 30, and 16 for the Bobtail soil.

Pots were soaked twice daily for 3 days before seeds were sown. Twenty seeds were carefully broadcast on the surface of each pot. All pots were then soaked again to insure that soil moisture was near saturation before watering treatments were begun. A total of 60 pots, 30 for each soil, 7 inches deep and 6 inches in diameter, were prepared.

Experimental design and treatments.—The experiment was a two-factor factorial with two soil types and five water levels, replicated six times. Soil types were arranged as a split plot with the following watering treatments randomized as main plots: 0.0, 0.5, 1.0, 1.5, and 2.0 inches monthly. Water was applied at the rate of 0.25 inch at each watering. The number of waterings and interval between each was determined by the assigned treatment.

Greenhouse environment.—Environment in the greenhouse at Fort Collins was maintained as closely as possible to average field conditions during the growing season at 10,500 feet elevation on the Fraser Experimental Forest. Air temperatures were 70° F. (± 2°) during the day and 40° F. (± 2°) at night. The photoperiod was 16 hours of natural and artificial light. The transition period of temperature changes coincided with light changes. Relative humidity varied from 20 to 30 percent during the day and 70 to 80 percent at night.

Measurements and analyses.—Number of germinating seeds, number of surviving seedlings, and cause of mortality were recorded biweekly. At the end of 24 weeks, the soil was carefully washed from the roots of all live seedlings, and the top height and root length were measured to the nearest millimeter. The tissue was then ovendried for 24 hours at 100° C. and weighed to the nearest 0.1 milligram.

Germination and survival were expressed as a percent of the number of seeds sown per pot; top height, root length, and total seedling dry weight were weighted pot means. Differences due to treatment were tested for significance by analyses of variance, with arc-sin transformation for percentage data. The means of significant effects were compared by Tukey's Test.

Results

Germination.—There were no significant differences in germination between soil types. Total germination increased from 12 percent to 50 percent as the amount of water received increased from 0.0 to 1.5 inches per month. Additional water did not significantly improve germination (fig. 1).

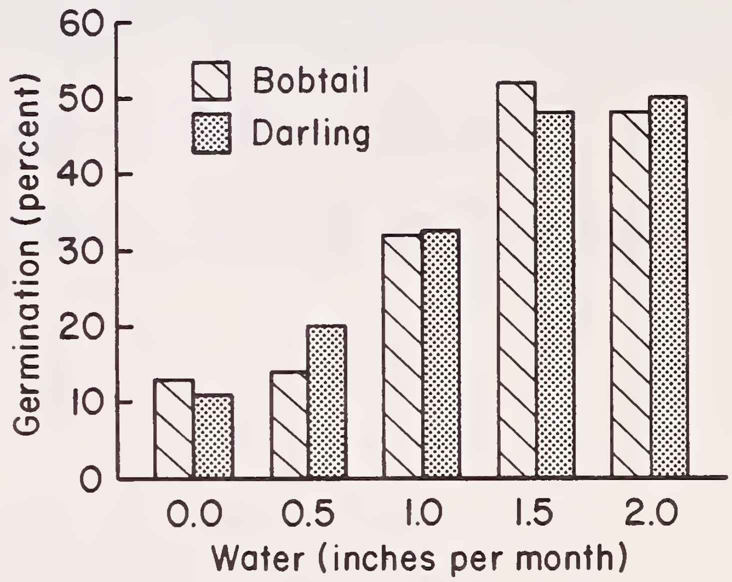

Figure 1.--Total germination in relation to soil type and watering treatment.

Germination in the unwatered treatment ended by the second week, and was completed in the 0.5-inch watering treatment after 3 weeks. Most seeds that germinated in the other treatments had emerged by the 4th week, but a few seedlings continued to emerge for as long as 10 weeks (fig. 2). The germination pattern was similar to that observed by Alexander and Noble (1971).

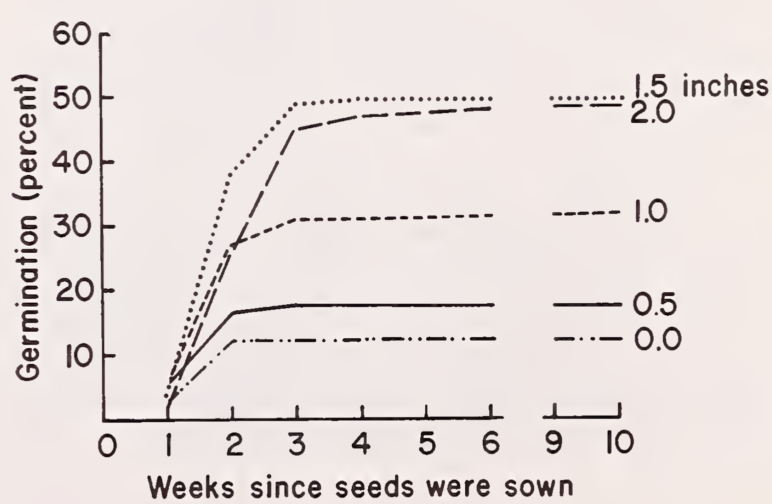

Figure 2.--Length and pattern of germination period in relation to watering treatment. (Soils were not significantly different.)

Seedling survival.—Number of seedlings surviving after 24 weeks was related both to amount of water received and soil type. In the Bobtail soils, 1.5 inches of water per month was required to sustain significant survival. In the Darling series, 1.0 inch monthly was sufficient (fig. 3).

In both soils, there was little difference in survival between the 1.5- and 2.0-inch watering treatments (fig. 3).

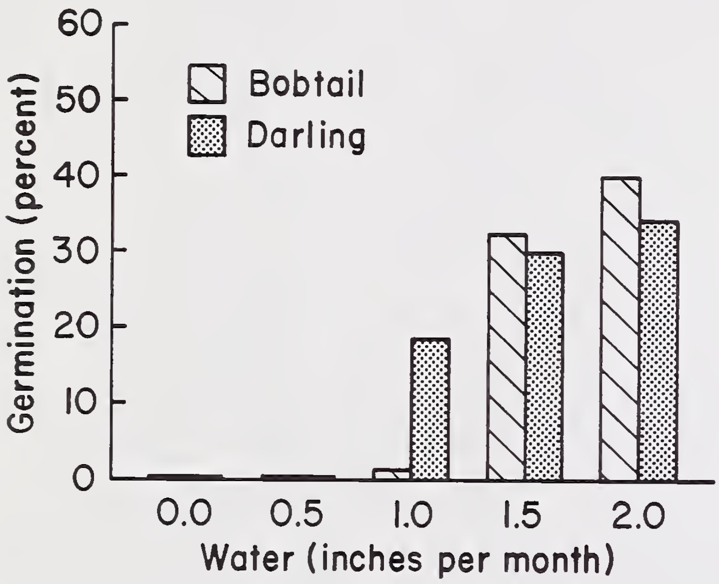

Figure 3.--Seedling survival after 24 weeks in relation to soil type and watering treatment.

Causes of mortality.—The basic difference between soils was in degree and not in cause of mortality (table 1).

1. Drought was the most important cause of seedling death in the Bobtail soil at watering treatments up to 1.5 inches, and accounted for 22 percent of the mortality in the 2.0-inch watering treatment. In the Darling soil, drought was a major factor in the 0.0- to 1.0-inch watering treatments, then dropped off rapidly to no loss in the 2.0-inch treatment.

2. Damping-off did not occur in either soil until 1.0 inch of water or more was applied per month. Two inches of water per month caused significant losses in both soils. Mortality occurred in the first 2 weeks following emergence in all watering treatments.

3. A seedling "failed to establish" if the radicle emerged from the seedcoat but did not become rooted. Possible causes may have been that seeds failed to imbibe sufficient water, did not have adequate food reserves, the soil surface was too hard for the radicle to penetrate, or any combination of these factors. Failure to establish was a consistent cause of death in the Bobtail soil at all watering levels, with the highest mortality in the 2.0-inch water treatment. The loss was serious only in the 1.5- and 2.0-inch water treatments in the Darling soil.

4. Death from a factor or factors that could not be determined was assigned to other causes.

Table 1.--Percent mortality, by cause and soil types among greenhouse-grown Engelmann spruce seedlings

Cause of mortality and soil type	Water per month				
	None	0.5 inch	1 inch	1.5 inches	2.0 inches
Drought					
Bobtail	93.8	76.5	75.7	56.5	22.2
Darling	100	95.8	82.4	28.6	0
Damping-off					
Bobtail	0	0	5.4	8.7	44.5
Darling	0	0	17.6	23.8	57.9
Failure to establish					
Bobtail	6.2	23.5	18.9	17.4	33.3
Darling	0	4.2	0	38.1	15.8
Other causes					
Bobtail	0	0	0	17.4	0
Darling	0	0	0	9.5	26.3

Seedling growth.—Top height and total plant dry weight in the 1.5- and 2.0-inch treatments — where survival was sufficient to make comparisons—were not significantly related to either soil type or amount of water. Roots in the Bobtail soil were significantly shorter (table 2), but were larger in diameter than in the Darling soil.

Table 2.--Engelmann spruce seedling growth in greenhouse by soil types and watering treatments

Growth by soil type	Water per month 1.0 inch	1.5 inches	2.0 inches
Height (cm)			
Bobtail	--	2.2	2.3
Darling	2.2	2.2	2.1
Root Length (cm)			
Bobtail	--	[1]15.1	[1]15.4
Darling	19.1	20.1	18.4
Dry Weight (mg)			
Bobtail	--	23.8	30.0
Darling	28.4	30.0	23.9

[1]Significant at the 99 percentile between soils.

Discussion and Conclusions

The greenhouse environment was more favorable for germination, survival, and growth of spruce seedlings than that likely to occur in the field. By combining data from this study with field observations, however, we can draw some inferences concerning the effect of the two soil types and various amounts of precipitation on germination and first-year seedling survival and growth.

The Bobtail soil formed a hard crust and compacted more in the greenhouse pots than did the Darling soil. Likewise, water soaked into the Bobtail soil more slowly. The crust on the Bobtail soil may explain why a consistent percent of seedlings failed to establish; the radicles had difficulty penetrating and becoming rooted.

Roots in the Bobtail soil may have encountered sufficient physical resistance from compaction so that, with only 1.0 inch of water, they could not elongate rapidly enough to maintain contact with available water. The physical resistance could also explain the shorter root lengths in the 1.5-inch and 2.0-inch watering levels. While the root diameters were not measured, it was obvious that they were not only shorter but thicker than roots from the Darling soil. The morphological difference was not reflected in root dry weights, however.

These observations suggest that soil crusting and compacting, as well as other unknown factors, influence developing seedlings. More study in the field and laboratory is needed to determine how soil characteristics and amount of water affect the ability of spruce seedlings to become established and survive.

The study showed that even small soil-related differences, when interacting with precipitation, can cause significant differences in survival and root elongation for Engelmann spruce seedlings during their first year of growth. Other weather and environmental factors also interact to affect regeneration success, however.

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